Chapter 4
Types and Sources of Wastes

4-1. Low-Level Radioactive Wastes

a. Sources.

(1) The three major sources of LLRW are power reactor operations, industrial and institutional activities, and government research and defense activities. The chemical, physical, and radiological characteristics of these wastes vary greatly from source to source. The chart given in Figure 4-1 shows general categories of radioactive wastes with the associated typical physical forms and sources for each category. Commercial nuclear fuel cycle facilities currently account for approximately three-fourths of the waste volume shipped to commercial disposal sites. The DOE generates LLRW through its defense activities, uranium enrichment operations, naval nuclear propulsion, and various research and development activities. The most common radionuclides found in LLRW and their production percentages by generator are given in Table 4-1.

(2) Power reactors produce a variety of both dry and wet LLRW. Exhausted ion exchange resins and sludges result from the treatment of liquid radioactive waste. Trash such as clothing, gloves, paper, equipment, filter cartridges, and activated metals comprise the majority of the dry LLRW produced during reactor operations.

(3) Industrial generators manufacture radionuclides for industrial, bioresearch, medical, and nonbioresearch uses. Table 4-2 shows the composition of industrial and institutional waste by category for 1990.

(4) Institutional generators include hospitals, private medical offices, medical research laboratories, colleges, universities, and research facilities. These wastes include trash, liquid scintillation vials, absorbed aqueous and organic liquids, and biological wastes such as patient excreta and animal carcasses. NARM wastes may also be produced from facilities with accelerators.

(5) The government produces the majority of LLRW; however, DOE is in charge of its own waste and does not fall under the jurisdiction of the NRC but does have to comply with EPA regulations. DOE activities, such as fuel fabrication and reactor operation, spent fuel storage, weapons production, chemical processing, and research and development using radionuclides and accelerators, result in a large volume of LLRW. Some of this waste has been disposed of onsite, and some has been sent to the commercial disposal facilities. Table 4-3 lists the historical annual additions and total volume of LLRW buried displayed by site.

b. Types.

(1) The designation of material as LLRW does not necessarily imply low hazard. Table 4-4 lists radionuclides commonly found in LLRW, their half-lives, principal mode of decay, and daughters. Most of these are beta and gamma emitters, with a small fraction being alpha emitters. These alpha emitters present a higher internal hazard, which is reflected in very low permissible concentration limits. Most of the radionuclides in the list have half-lives less than 100 years. The predominant long-lived radionuclide in non-fuel-cycle waste is ^{3}H. In power production, or fuel-cycle waste, the predominant long-lived nuclides are ^{60}Co, ^{90}Sr, and ^{137}Cs. In the accelerator-produced waste, most of the radionuclides are very short-lived and will decay to acceptable levels if stored for a short time. However, the waste may contain naturally occurring radionuclides such as uranium, thorium, and radium, which are very long-lived.

(2) Waste found at DOE sites has unique characteristics because of the research and development aspects of government work. Table 4-5 lists representative DOE LLRW radionuclide composition by percent activity. Table 4-6 is a summary of radionuclide characteristics for LLRW at DOE sites, and Table 4-7 is a summary of physical characteristics for LLRW at the DOE sites.

4-2. Hazardous Wastes

a. Sources. A material becomes a hazardous waste if it meets the definition of hazardous waste set forth in RCRA and CERCLA. Hundreds of substances are considered hazardous and are generated everywhere from dry cleaning businesses to the DOE and DOD. Hazardous wastes which are of concern in this manual are those that come into contact with radioactive wastes.

b. Types. A hazardous waste can be either a listed waste or a characteristic waste. Listed wastes are wastes that have been listed by EPA in 40 CFR 261 Subpart D and have not been specifically delisted. Characteristic wastes are wastes that exhibit any of the four characteristics for identifying hazardous waste in 40 CFR 261 Subpart C, which are ignitability, corrosivity, reactivity, and toxicity characteristic leaching procedure (TCLP) toxicity. The major classes of hazardous wastes are volatile organic compounds, semivolatile organic compounds, and

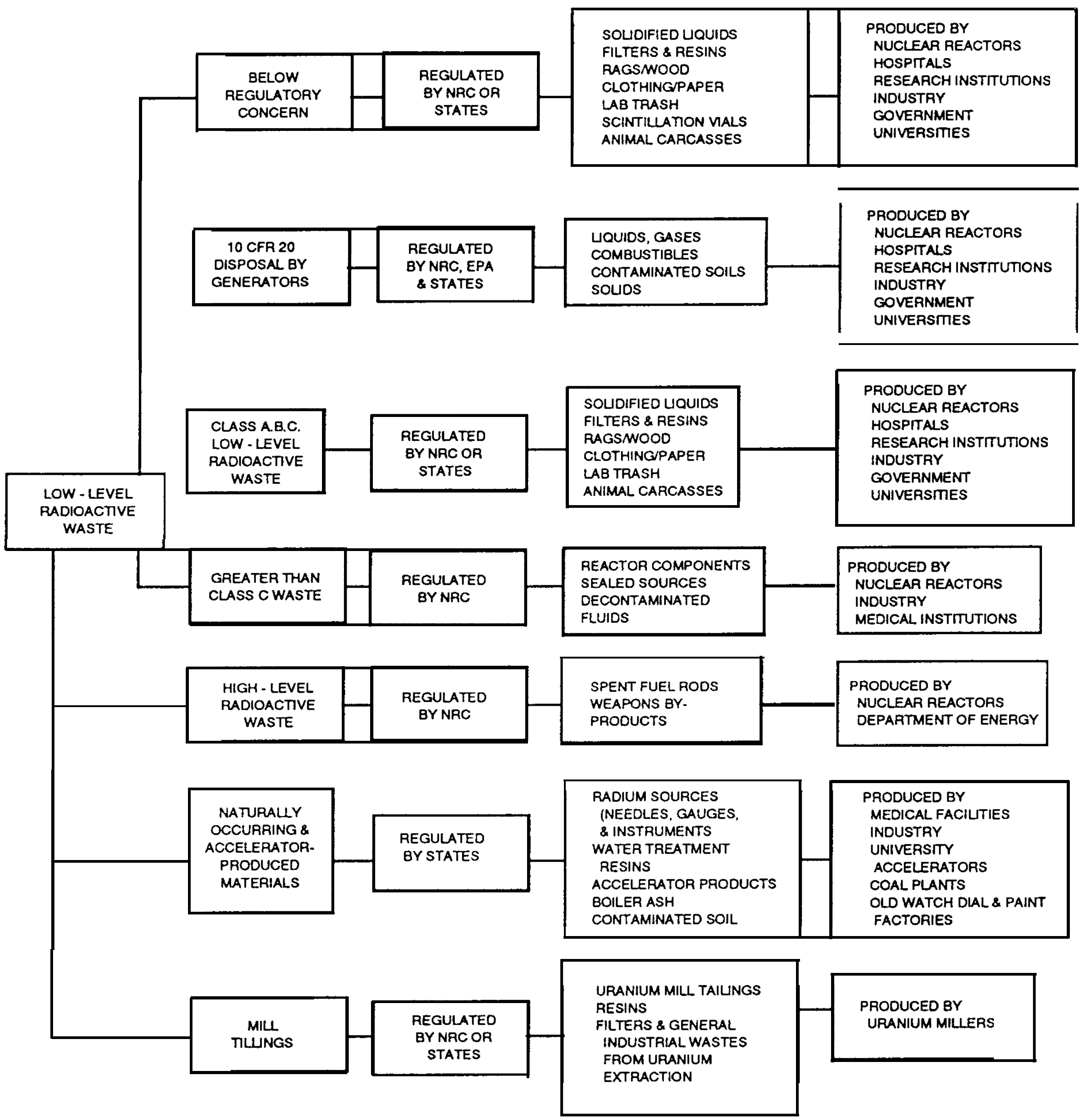

Figure 4-1. Types of reactionless LLRW

Table 4-1
Typical Radionuclides Present in LLRW by Generator

		Activity (%)				
Radionuclide	Half-Life	Fuel Cycle	Industry	Institutional	Clinical	Government
<90 day half-life						
^{99m}Tc	6.0 hours			8	96	
^{99}Mo	66.7			3		
^{21m}Tl	74.0				1-2	-
^{67}Ga	78.1			3	1-2	-
^{131}I	8.1 days			1	0.2	-
^{32}p[1]	14.3			22	-	7
^{66}Rb	18.7			<1	-	7
^{126}I	60.2			9	-	7
^{192}Ir	74.2		7	<1		
^{33}S[1]	88.0		<1	22		7
>90 days and <5 years half-life						
^{134}Cs	2.1 years	18	<1	-	-	-
^{22}Na[1]	2.6		-	<1	-	7
>5 years and <100 years half-life						
^{60}Co	5.3 years	16	1	<1	-	-
^{3}H[1]	12.3	2	88	29	-	55
^{137}Cs	30.0	36	<1	<1	-	-
>100 years half-life						
^{14}C[1]	5,730 years	-	<1	1	-	10
^{99}Tc	210,000	<1	-	2	-	-
Uranium and TRU	$>10^5$	-	3	<1	-	-
Mixed fission [1,2]	$>10^6$	25	-	-	-	-
Total		98	99	100	100	100

[1] Naturally occurring isolupe.
[2] Mixed fission products include radioactive xenon, krypton, bromine, iodine, tellurium, ruthernium, stronthum, and barium. With the exceptions of ^{129}I, ^{90}Sr, and ^{85}Kr, all have half-lives shorter than one year.

Source: Gershey et al. 1990.

metals. Hazardous materials that may end up as a mixed waste include contaminated organic solvents and laboratory liquids, sludges, oils, discarded lead shielding, discarded lined containers, cadmium wastes, and mercury wastes.

4-3. Mixed Wastes

a. Sources.

(1) Mixed LLRW is generated by the same sources as LLRW. Mixed waste arises from processes in which LLRW and hazardous wastes must be combined. Typically, mixed LLRW at DOE sites includes a variety of contaminated materials, such as air filters, cleaning solutions and cleanup materials, engine oils and grease, epoxies and resins, laser dyes, paint residues, photographic materials, soils, asphalts, roofing compounds and wall materials, water treatment chemicals, and decommissioned weapons manufacturing equipment. Figures 4-2 and 4-3 exhibit the total volume inventory of DOE mixed LLRW through 1990 and the volume generation during 1990. Tables 4-8 through 4-10 list the volume inventories of DOE site mixed LLRW, by physical category, through 1990, and Table 4-11 lists the volume

Table 4-2
Composition of Industrial and Institutional Waste by Category[1]

	Composition, %[2]				
		Institutional			
Radionuclide	Industrial	Bioresearch	Medical	Nonbioresearch	Total
^{3}H	6.453E+01	5.286E+01	8.341E+00	8.324E+01	6.319E+01
^{14}C	3.815E-01	2.738E+0	8.107E+00	6.549E+00	4.454E+00
^{22}Na		1.652E-01			2.279E-02
^{32}P	6.340E+00	4.416E+00	7.367E+00		5.316E+00
^{36}Ce		3.239E-02			4.469E-03
^{35}S	5.519E+00	4.294E+00	8.735E-01		5.042E+00
^{45}Ca	8.671E-04	2.242E-02			3.791E-03
^{46}Sc			1.911E-02		2.571E-04
^{51}Cr	1.394E-01	2.775E-01	3.417E-01		1.55OE-01
^{54}Mn	8.052E-02			3.987E-02	6.654E-02
^{55}Fe	2.336E-03	2.092E-03		6.577E-01	3.102E-02
^{57}Co	4.584E-03		6.575E-01		1.252E-02
^{58}Co	2.228E-03	2.318E-02			4.992E-03
^{59}Fe	9.859E-04			1.551E-02	1.473E-03
^{60}Co	3.366E+00			8.230E-01	2.748E+00
^{63}Ni	9.752E-03			5.037E-02	1.006E-02
^{65}Zn	1.196E-03	5.929E-02		1.398E-01	1.482E-02
^{67}Ga			7.758E-02		1.043E-03
^{75}Se	1.341E-02		2.419E-02		1.112E-02
^{85}Kr	4.061E-02				3.267E-02
^{90}Sr	3.310E-01				2.663E-01
^{90}Y	3.310E-01				2.663E-01
^{90}Mo			2.317E+00		3.114E-02
^{99m}Tc			7.023E-01		9.349E-03
^{109}Cd	8.790E-02				7.071E-02
^{111}In	6.475E-04		2.800E-02		8.969E-04
^{113}Sn			2.410E-02		3.240E-04
^{123}I	5.063E-04		2.190E-02		7.016E-04
^{126}I	1.703E+00	9.902E+00	7.064E+01		3.586E+00
^{131}I	1.465E-02	5.452E-01	5.652E-02		8.778E-02
^{133}Ba	2.674E-02				2.151E-02
^{133}Xe			3.828E-02		5.146E-04
^{134}Cs	2.605E-02				2.096E-02
^{137}Cs	6.008E+00	1.230E-02		1.250E+00	4.892E+00
^{137m}Ga	5.687E+00	1.164E-02		1.183E+00	4.525E+00

[Continued)

[1]The volumetric composition of 1/1 is considered to be as follows: 70.3% industrial, 21.9% bioresearch, 2.3% medical, and 5.5% nonbioresearch. The radioactivity composition of 1/1 waste is considered to be: 80.5% industrial, 13.8% bioresearch, 1.3% medical and 4.4% nonbioresearch.
[2]Composition is presented as percent of total curies in each individual category of 1/1 waste and as percent of the total in all 1/1 waste combined.
Source: DOE 1991

Table 4-2 (Concluded)

	Composition, %[2]				
		Institutional			
Radionuclide	Industrial	Bioresearch	Medical	Nonbioresearch	Total
^{147}Pm	1.015E-01				6.167E-02
^{161}Sm	6.166E-03				4.960E-03
^{163}Gd			5.288E-03		7.107E-05
^{165}Yd	8.637E-02				5.948E-02
^{176}Hf	1.234E-02				9.924E-03
^{182}Ta	7.939E-01				5.387E-01
^{192}Ir	3.347E-01		1.995E+00		2.961E-01
^{201}T1			2.585E-01		3.476E-03
^{210}Po	1.424E-01				1.146E-01
^{226}Ra			1.071E-01		1.439E-03
^{230}Th	7.489E-04				6.047E-03
^{232}Th	1.665E+00				1.341E+00
^{235}U	1.356E-02				1.091E-02
^{238}U	2.172E+00			9.484E-01	1.807E+00
^{241}Pu	1.806E-02				1.453E-02
Total	1.000E+02	1.000E+02	1.000E+02	1.000E+02	1.000E+02

inventories of DOE site mixed LLRW, by physical category, for 1990. The acronyms used in Figures 4-2 and 4-3 are explained below. These sites are also the major contributors to the inventories listed in Tables 4-8 through 4-10. Tables 4-8 through 4-10 are taken from the report "Quantities and Characteristics of the Contact-Handled Low-Level Mixed Waste Streams for the DOE Complex," done by the Idaho National Engineering Laboratory for the Integrated Thermal Treatment Study (ITTS). Thus, the smaller contributors' acronyms are not listed but can be found in DOE's 1991 integrated database.

HANF	Hanford Reservation, Washington
PORTS	Portsmouth Gaseous Diffusion Plant, Ohio
INEL	Idaho National Engineering Laboratory, Idaho
RFP	Rocky Flats Plant, Colorado
SRS	Savannah River Site, South Carolina
Y-12	Munitions Plant, Oak Ridge, Tennessee
K-25	Gaseous Diffusion Plant, Oak Ridge, Tennessee

(2) of the commercial LLRW generated, approximately 3-10 percent is mixed LLRW. If the total accumulated commercial LLRW disposal volume through 1990 is taken to be 1,384,000 m^3, then approximately 41,000-138,400 m^3 of mixed LLRW has been generated.

b. Types. Chemical properties of mixed LLRW are described by the following five categories of waste types: listed, ignitable, reactive, corrosive, and TCLP/EP (toxicity characteristic leaching procedure/extraction procedure) toxic. From commercial facilities, institutions, and plants, the following 12 categories of mixed waste have been identified:

(1) Liquid scintillation cocktails or fluids from laboratory counting activities. (These are no longer considered mixed waste.)

(2) Organic chemicals, including residues from research and manufacturing activities, spent reagents from experiments, residues from cleaning laboratory and process equipment, and expired products.

(3) Trash with organic chemicals, including used research equipment.

(4) Lead, including residues and contaminated materials.

(5) Lead solutions from lead shielding decontamination.

Table 4-3
Historical Annual Additions and Total Volume of LLW Buried at DOE Sites[1]

	Volume of Waste Buried Annually, $10^3 m^3$										
Year	FMPC	HANF	INEL	LANL	NTS	ORNL	SRS	Y-12	All Other[2]	Total Annual Addition	Total Volume Accumulated
1975[3]	264.7	358.8	84.6	131.6	8.3	181.5	256.7	58.4	83.9	1,428,5	1,429
1976	14.4	5.3	6.2	8.8	0.0	3.8	7.9	2.7	0.9	50.0	1,479
1977	2.8	11.3	6.6	3.6	0.5	2,4	14.9	1.5	1.1	44.7	1,523
1978	1.9	10.4	5.9	7.5	10.4	2.0	15.9	1.4	3.2	58.6	1,582
1979	1.6	17.9	5.3	4.9	15.8	2.1	16.5	1.1	1.1	66.3	1,648
1980	1.3	11.3	5.1	4.8	13.3	2.0	19.8	1.4	0.7	59.7	1,708
1981	1.5	13.5	3.1	5.5	21.1	1.4	20.3	1.2	1.6	69.2	1,777
1982	2.8	12.2	3.2	4.5	56.8	1.3	22.5	2.2	2,0	107.5	1,885
1983	3.4	18.3	5.5	3.2	12.1	1.8	26.7	3.4	1.7	76.1	1,961
1984	3.5	19.1	3.9	5.4	36.0	2.2	26.2	7.2	10.6	114.1	2,075
1985	0.7	17.5	3.1	6.7	41.7	2.2	30.7	18.7	2.1	123.4	2,198
1986	0.0	21.2	3.4	4.5	27.9	1.8	30.1	15.0	1.0	104.9	2,303
1987	0.0	20.4	3.0	3.7	81.1	0.5	34.1	16.2	1.0	160.0	2,463
1988	0.0	16.8	2.0	4.3	39.1	0.6	36.7	10.5	1.0	111.0	2,574
1989	0.0	11.9	1.3	6.4	35.0	1.3	27.2	5.7	2.1	90,9	2,665
1990	0.0	7.9	1.8	4.5	9.1	0,3	26.6	4.4	0.0	54.6	2,720
TOTAL	298.5	573.8[4]	144.0	209.9	408.4	207.2	612.8	150.9	114,1	2,720	

[1] No TRU waste included; slight difference in values shown and those actually reported result from rounding off and trucation of numbers.
[2] Includes contributions from Ames, BNL, K-25, LLNL, PAD, PORTS, SLAC, and SNLA.
[3] Values from 1975 are cumulative volumes to this date.
[4] Does not include 5,190m^3 of grouted-liquid LLW disposed of at Hanford.

Source: DOE 1991

Table 4-4
Characteristics of Important Radionuclides

Nuclide	Atomic Number	Half-life[1]	Principal mode(s) of decay[2]	Major Radiation Energies[3] MeV/dis σ	Θ	$Y^{(x)}$	"Q" Value[4] (MeV/dis)	(W/Ci)	Specific Activity Ci/o	Daughter(s)
^{3}H	1	1.233E+01 y	β		0.00568		5.68E-03	3.37E-05	9.650E+03	^{3}Ho
^{14}C	6	5.730E+03 y	β		0.0495		4.95E-02	2.93E-04	4.457	^{14}N
^{32}P	15	14.282 d	β		0.6947		6.95E-01	4.12E-03	2.853E+05	^{32}S
^{35}S	16	87.51 d	β		0.0486		4.86E-02	2.88E-04	4.263E-04	^{35}Cl
^{36}Cl	17	3.01E+05 y	β (98.1%); EC (1.9%)		0.2460		2.460E-01	1.458E-0	3.299E-02	^{36}Ar ^{36}S
^{45}Ca	20	163.8 d	β		0.0770		7.70E-02	4.56E-04	1.780E+04	^{45}So
^{46}Sc	21	83.83 d	β	0.1120	2.0095		2.122E+00	1.257E-02	3.381E+04	^{46}Tl
^{51}Cr	24	27.704 d	EC		0.0031	0.0325	3.56E-02	2.11E-04	9.240E+04	^{51}V
^{54}Mn	25	312.20 d	EC		0.0034	0.8360	8.394E-01	4.975E-03	7.738E+03	^{54}lCr
^{55}Fe	26	2.73 y	EC		0.0038	0.0016	5.4E-03	3.2E-05	2.500E+03	^{55}Mn
^{59}Fe	26	44.496 d	β		0.1174	1.1882	1.3056	7.741E-03	4.918E+04	^{59}Co
^{57}Co	27	271.77 d	EC		0.0176	0.1252	1.428E-01	8.464E-01	8.456E+03	^{57}Fa
^{58}Co	27	70.92 d	EC		0.0336	0.9758	1.0094	5.99E-03	3.181E+04	^{58}Fa
^{60}Co	27	5.271 y	β		0.0958	2.5058	2.6016	1.541E-02	1.131E+03	^{60}Ni
^{60m}Co	27	10.47 min	IT (99.75%) β (0.25%)		0.0536	0.0066	6.02E-02	3.57E-04	2.993E+08	^{60}Co; ^{60}Ni
^{59}Ni	28	7.5E+04 y	EC		0.0043	0.0024	6.72E-03	3.98E-05	7.574E+04	^{59}Co
^{63}Ni	28	1.001E+02 y	β		0.0171		1.71E-02	1.01E-04	6.168E+01	^{63}Cu
^{63}Zn	30	244.1 d	EC		0.0066	0.5838	5.90E-01	3.51E-03	8.237E+03	^{65}Cu
^{67}Ga	31	3.261 d	EC		0.0333	0.1540	1.882E-01	1.115E-03	5.975E+05	^{67}Zn
^{75}Sa	34	119.77 d	EC		0.0134	0.3924	4.06E-01	2.41E-03	1.453E+04	^{75}As
^{79}Sa	34	<6.5E+04 y			0.0529		5.29E-02	3.13E-04	6.966E-02	^{79}Br
^{85}Kr	36	1.072E+01 y	β		0.2505	0.0022	2.53E-01	1.50E-03	3.923E+02	^{85}Rb
^{86}Rb	37	18.66 d	β		0.6670	0.0945	7.62E-01	4.52E-03	8.138E+04	^{86}Sr

(Sheet 1 of 6)

[1] y - years; d - days; h - hours; min - minutes; and s - seconds.
[2] α - alpha decay; β - negative beta decay; EC - electron capture; IT - isomeric transition (radioactive transition from one nuclear isomer to another of lower energy); and SPF - spontaneous fission.
[3] α - alpha decay; θ - total electron emissions; and $Y^{(x)}$ - gamma and X-ray photons.
[4] The sum of the average energies per different radiation types in MeV/disintegration or W/Ci (includes alpha and beta particles, discrete electrons, and photons). The "Q" value indicates the amount of energy (heat) that could be deposited in a radioactive material from each decay event if none of the radiation escaped from the material.

Source: DOE 1991

Table 4-4. (Continued)

Nuclide	Atomic Number	Half-life[1]	Principal mode(s) of decay[2]	Major Radiation Energies[3] MeV/dis σ	Θ	Y[(x)]	"Q" Value[4] (MeV/dis)	(W/Ci)	Specific Activity Ci/o	Daughter(s)
^{89}Sr	38	50.55 d	β		0.5829	0.0001	5.83E-01	3.46E-03	2.905E+04	^{89}Y
^{90}Sr	38	2.85E+01 y	β		0.1958		1.96E-01	1.16E-03	1.364E+02	^{90}Y
^{90}Y	39	2.671 d	β		0.9332		9.33E-01	5.54E-03	5.441E+05	^{90}Zr
^{91}Y	39	58.51 d	β		0.6039	0.0036	6.07E-01	3.60E-03	2.452E+04	^{91}Zr
^{93}Zr	40	1.53E+06 y	β		0.0471	0.0018	4.89E-02	2.90E-04	2.513E-03	^{93}Nb
^{95}Zr	40	64.02 d	β		0.1200	0.7337	8.54E-01	5.06E-03	2.148E+04	^{95}Nb
^{93m}Nb	41	1.36E+01 y	IT		0.0281	0.0018	2.99E-02	1.77E-04	2.826E+02	^{93}Nb
^{94}Nb	41	2.03E+04 y	β		0.1454	1.5715	1.7169	1.018E-02	1.873E-01	^{94}Mo
^{95}Nb	41	34.97 d	β		0.0435	0.7643	8.078E-01	4.788E-03	3.910E+04	^{95}Mo
^{99}Mo	42	2.748 d	β		0.4076	0.2723	6.799E-03	4.028E-03	4.796E+05	^{99}To
^{99}Tc	43	2.13E+05 y	β		0.0846		8.46E-02	5.01E-04	1.695E-02	^{99}Ru
^{99m}Tc	43	6.006 h	IT		0.0142	0.1240	1.382E-01	8.186E-04	5.271E+06	^{99}Tc
^{103}Ru	44	39.254 d	β		0.1105	0.4851	5.96E-01	3.53E-03	3.277E+04	^{103}Rh
^{106}Ru	44	1.020 y	β		0.1004		1.004E-01	5.951E-04	3.346E+06	^{106}Rh
^{103m}Rh	45	56.12 min	IT		0.0375	0.0017	3.92E-02	2.32E-04	3.253E+07	^{103}Rh
^{106}Rh	45	2.17 h	β		0.3144	2.8826	3.197	1.894E-02	3.560E+09	^{106}Pd
^{107}Pd	46	6.5E+06 y	β			0.0093	9.3E-03	5.5E-05	5.143E-04	^{107}Ag
^{110}Ag	47	24.6 s	β(99.70%) EC (0.30%)		1.842	0.0316-	1.216	7.208E-03	4.169E+09	^{110}Cd; ^{110}Pd
^{110m}Ag	47	249.76 d	β(96.64 %) IT(1.36%)		0.0755	2.7392	2.815	1.669E-02	4.750E+03	^{110}Cd; ^{110}Ag
^{113m}Cd	48	1.37E+01 y	β(99.9%) IT(0.1%)			0.1834	1.83E-01	1.08E-03	2.168E+02	^{113}In; ^{113}Cd
^{115m}Cd	48	44.6 d	β		0.6029	0,0329	6.36E-01	3.76E-03	2.546E+04	^{115}In
^{111}In	49	2.807 d	EC		0.0340	0.4053	4.393E-01	2.604E-03	4.157E+05	^{111}Cd
^{113m}In	49	1.658 h	IT		0.1340	0.2555	3.89E-01	2.31E-03	1.673E+07	^{113}In
^{114m}In	49	49.51 d	IT(95.7%) EC(4.3%)		0.1431	0.0943	2.37E-01	1.40E-03	2.313E+04	^{114}In; ^{114}Cd
^{113}Sn	50	115.09 d	EC		0.1394	0.2808	4.20E-01	2.48E-03	1.004E+04	^{113}In
^{117m}Sn	50	13.61 d	IT		0.1613	0.1580	3.19E-01	1.89E-03	7.969E+04	^{117}Sn
^{119m}Sn	50	293.0 d	IT		0.0783	0.0114	8.97E-01	5.32E-04	4.478E+03	^{119}Sn
^{121m}Sn	50	5.5E+01 y	IT(77.6%) /3(22.4%)		0.0352	0.0050	4.02E-02	2.43E-04	5.912E+01	^{121}Sn ^{121}Sb

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Table 4-4. (Continued)

Nuclide	Atomic Number	Half-life[1]	Principal mode(s) of decay[2]	Major Radiation Energies[3] MeV/dis			"Q" Value[4]		Specific Activity	Daughter(s)
				σ	Θ	$Y^{(x)}$	(MeV/dis)	(W/Ci)	Ci/o	
^{123m}Sn	50	129.2 d	β		0.5222	0.0069	5.29E-01	3.14E-03	8.219E+03	^{123}Sb
^{125}Sn	50	9.64 d	β		0.8110	0.3124	1.123	6.656E-03	1.084E+05	^{125}Sb
^{126}Sn	50	~1E+05 y	β		0.1249	0.0573	1.82E-01	1.08E-03	2.837E-02	^{126}Sb
^{124}Sb	51	60.20 d	β		0.3897	1.8523	2.242	1.329E-02	1.749E+04	^{124}To
^{126}Sb	51	2.73 y	β		0.1257	0.4434	5.69E-01	3.37E-03	1.032E+03	^{126}To
^{128}Sb	51	12.4 d	β		0.3527	2.7496	3.102	1.839E-02	8.360E+04	^{128}To
^{128m}Sb	51	19.0 min	β(86%) IT(14%)							
^{123m}To	52	119.7 d	IT		0.1020	0.1482	2.502E-01	1.482E-03	8.870E+03	^{123}To
^{125m}To	52	58 d	IT		0.1106	0.0361	1.467E-01	8.690E-04	1.801E+04	^{125}To
^{127}To	52	9.35 h	β		0.2248	0.0048	2.30E-01	1.36E-03	2.639E+06	^{127}I
^{127m}To	52	109 d	IT(97.6%) β(2.4%)		0.0821	0.0111	9.32E-02	5.52E-04	9.432E+03	^{127}To ^{127}I
^{129}To	52	1.160 h	β		0.5422	0.0624	6.05E-01	3.58E-03	2.094E+07	^{129}I
^{129m}To	52	33.6 d	IT(64%) β(36%)		0.2663	0.0370	3.03E-01	1.80E-03	3.013E+04	^{129}To
^{123}I	53	13.2 h	EC		0.0276	0.1729	2.005E-01	1.188E-03	1.940E+06	^{123}To
^{125}I	53	60.14 d	EC		0.0179	0.0423	6.02E-02	3.57E-04	1.737E+04	^{125}To
^{129}I	53	1.57E+07 y	β		0.0556	0.0248	8.04E-02	4.77E-04	1.765E-04	^{129}Xo
^{131}I	53	8.040 d	β		0.1913	0.3826	5.74E-01	3.40E-03	1.240E+05	^{130}Xo
^{133}Xo	54	5.245 d	β		0.1363	0.0459	1.82E-01	1.08E-03	1.872E+05	^{133}Cs
^{134}Cs	55	2.062 y	β		0.1639	1.5555	1.719	1.019E-02	1.294E+03	^{134}Ba
^{136}Cs	55	3.0E+06 y	β		0.0563		5.63E-02	3.32E-04	1.151E-03	^{135}Ba
^{137}Cs	55	3.00E+01 y	β(94.6%) β(5.4%)			0.1708	1.71E-01	1.01E-03	8.698E+01	^{137m}Ba ^{137}Ba
^{133}Ba	56	1.054E+01 y	EC		0.0547	0.4045	4.592E-01	2.722E-03	2.500E+02	^{133}Ca
^{137m}Ba	56	2.552 min	IT			0.6616	6.64E-02	3.94E-03	5.379E+08	^{137}Ba
^{141}Ca	58	32.50 d	β		0.1707	0.0070	2.48E-01	1.47E-03	2.848E+04	^{141}Pr
^{144}Ca	58	284.9 d	β		0.0918	0.0192	1.11E-01	6.58E-03	3.190E+03	^{144}Pr
^{143}Pr	59	13.58 d	β		0.3156		3.16E-01	1.87E-03	6.731E+04	^{143}Nd
^{144}Pr	59	17.28 min	β		1.2091	0.0289	1.238	7.338E-03	7.555E+07	^{144}Nd
^{144m}Pr	59	7.2 min	IT(99.96%) β(0.04%)		0.0464	0.0121	5.58E-02	3.43E-04	1.814E+08	^{144}Pr ^{144}Nd

(Sheet 3 of 6)

Table 4-4. (Continued)

Nuclide	Atomic Number	Half-life[1]	Principal mode(s) of decay[2]	Major Radiation Energies[3] MeV/dis σ	Θ	Y(x)	"Q" Value[4] (MeV/dis)	(W/Ci)	Specific Activity Ci/g	Daughter(s)
^{146}Pm	61	5.53 y	EC(66.1%) β(33.9%)		0.0928	0,7542	8.47E-01	5.02E-03	4.428E+02	^{146}Nd; ^{146}Sm
^{147}Pm	61	2.6234 y	β		0.6196		6.20E-02	3.67E-04	9.27E+02	^{147}Sm
^{148}Pm	61	5.370 d	β		0.7235	0.5747	1.298	7.691E-03	1.643E+05	^{148}Sm
^{148m}Pm	61	41.29 d	β(95.4%) IT(4.6%)		0.1695	1.9861	2.156	1.27E-02	2.136E+04	^{148}Sm ^{148}Pm
^{151}Sm	62	9.0E-01 y	β		0.1251		1.25E-01	7.41E-04	2.631E+01	^{151}Eu
^{152}Eu	63	1.333E+01 y	EC(72.08%) β(27.92%)		0.1275	1.1628	1.290	7.646E-03	1.729E+02	^{152}Sm ^{152}Gd
^{154}Eu	63	8.8 y	β		0.2794	1.2531	1.532	9.081E-03	2.699E+02	^{154}Gd
^{155}Eu	63	4.96 y	β		0.0650	0.0633	1.28E-01	7.59E-04	4.651E+02	^{155}Gd
^{153}Gd	64	241.6 d	EC		0.0390	0.1015	1.414E-01	8.381E-04	3.526E+03	^{153}Eu
^{160}Tb	65	72.3 d	β		0.2535	1.1271	1.381	8.186E-03	1.129E+04	^{160}Dy
^{169}Yb	70	32.02 d	EC		0.1117	0,3121	4.238E-01	2.512E-03	2.414E+04	^{169}Tm
^{175}Hf	72	70.0 d	EC		0.0439	0.3646	4.085E-01	2.422E-03	1.066E+04	^{176}Lu
^{182}Ta	73	115.0 d	β		0.2073	1.3011	1.508	8.940E-03	6.253E+03	^{182}W
^{192}Ir	77	73.831 d	β(95.4%) EC(4.6%)		0.2162	0.8137	1.030	6.105E-03	9.211E+03	^{192}Pt; ^{192}Os
^{201}Tl	81	3.046 d	EC		0.0481	0.0924	1.40E-01	8.30E-04	2.132E+05	^{201}Hg
^{207}Tl	81	4.77 min	β		0.4931	0.0022	4.95E-01	2.93E-03	1.904E+08	^{207}Pb
^{208}Tl	81	3.053 min	β		0.5979	3.3742	3.972	2.354E-02	2.945E+08	^{208}Pb
^{209}Pb	82	3.253 h	β		0.1980		1.98E-01	1.17E-03	4.544E+05	^{209}Bi
^{211}Pb	82	36.1 min	β		0.4523	0.0678	5.20E-01	3.083E-03	2.466E+07	^{211}Bi
^{212}Pb	82	10.64 h	β		0.1752	0.1453	3.20E-01	1.90E-03	1.389E+08	^{212}Bi
^{211}Bi	83	2.14 min	α(99.727%) β(0.273%)	6.5505	0.0090	0.0467	6.607	3.916E-02	4.184E+08	^{207}Tl; ^{211}Po;
^{212}Bi	83	1.0092 h	α(35.94%) α(64.06%)	2.1740	0.5025	0.1061	2.783	1.649D-02	1.465E+07	^{208}Tl; ^{212}Po
^{213}Bi	83	45.59 min	α(2.16%) β(97.84%)	0.1268	0.4563	0.0825	66.6E-01	3.95E-03	1.934E+07	^{209}Tl; ^{213}Po
^{212}Po	84	2.98E-07 s	α	8.7844			8.784	5.207E-02	1.774E+17	^{208}Pb
^{213}Po	84	4.2E-06 s	α	8.3757			8.375	4.964E-02	1.261E+16	^{209}Pb
^{215}Po	84	1.780E-03 s	α	7.3864			7.386	4.378E-02	2.948E+13	^{211}Pb
^{216}Po	84	1.50E-02 s	α	6.7785			6.779	4.018E-02	3.482E+11	^{212}Pb

(Sheet 4 of 6)

Table 4-4. (Continued)

Nuclide	Atomic Number	Half-life[1]	Principal mode(s) of decay[2]	Major Radiation Energies[3] MeV/dis			"Q" Value[4]		Specific Activity Ci/g	Daughter(s)
				σ	Θ	Y[(x)]	(MeV/dis)	(W/Ci)		
^{217}At	85	3.23E-02 s	α	7.0657		**0.0002**	7.066	4.189E-02	1.610E+12	^{213}B;
^{219}Rn	86	3.96 s	α	6.8122	**0.0064**	**0.0560**	6.875	4.076E-02	1.301E+10	^{215}Po
^{220}Rn	86	55.6 s	α	6.2878		**0.0005**	6.288	3.727E-02	9.223E+08	^{216}Po
^{222}Rn	86	3.825 d	α	5.4892		**0.0004**	5.480	3.255E-02	1.538E+05	^{218}Po
^{221}Fr	87	4.9 min	α	6.3571	**0.0084**	**0.0277**	6.393	3.789E-02	1.772E+08	^{217}At
^{223}Fr	87	21.8 min	β		**0.3805**	**0.0542**	4.35E-01	2.85E-03	3.868E+07	^{223}Ra
^{223}Ra	88	11.43 d	α	5.6972	**0,0731**	**0.1348**	5.905	3.500E-02	5.121E+04	^{219}Rn
^{224}Ra	88	3.66 d	α	5.6751	**0.0022**	**0.0103**	5.688	3.372E-02	1.593E+05	^{220}Rn
^{225}Ra	88	14.2 d	β		**0.1057**	**0.0137**	1.19E-01	7.08E-04	3.920E+04	^{225}Ac
^{226}Ra	88	1.600E+03 y	α	4.7741	**0.0035**	**0.0067**	4.784	2.836E-02	9.887E-01	^{222}Rn
^{228}Ra	88	5.75 y	β		**0,0116**		1.16E-02	6.88E-05	2.340E+02	^{228}Ac
^{225}Ac	89	10.0 d	α	5.7501	**0.0257**	**0.0176**	5.793	3.434E-02	5.803E+04	^{221}Fr
^{227}Ac	89	2.177E+01 y	β(98.62%) α(1.38%)	0.0673	**0.0123**	**0.0002**	8.00E-02	4.74E-04	7.233E+01	^{227}Th; ^{223}Fr
^{228}Ac	89	6.13 h	β		**0,4292**	**0.9269**	1.356	8.038E-03	2.242E+06	^{228}Th
^{227}Th	90	18.718 d	α	5.9022	**0.0543**	**0.113**	6.068	3.597E-02	3.073E+04	^{223}Ra
^{228}Th	90	1.913 y	α	5.3992	**0.0201**	**0.0034**	5.423	3.214E-02	8.196E+02	^{224}Ra
^{229}Th	90	7.340E+03 y	α	4.8620		**0.0343**	4.896	2.902E-02	2.127E-01	^{225}Ra
^{230}Th	90	7.54E+04 y	α	4.6651		**0.0004**	4.665	2.765E-02	2.109E-02	^{226}Ra
^{231}Th	90	1.0633 d	β	0.1732		**0.0295**	2.03E-01	1.21E-03	5.316E+05	^{231}Pa
^{232}Th	90	1.405E+10 y	α	4.0056		**0.0002**	4.006	2.375E-02	1.097E-07	^{226}Ra
^{234}Th	90	24.10 d	β		**0.0158**	**0.0094**	2.52E-02	1.49E-04	2.136E+04	^{234}Pa
^{231}Pa	91	3.276E+04 y	α	4.9230	**0.0483**	**0.0399**	5.011	2.970E-02	4.723E-02	^{227}Ac
^{233}Pa	91	27.0 d	β		**0.1941**	**0.2042**	3.98E-01	2.36E-03	2.075E+04	^{233}U
^{234m}Pa	91	1.17 min	β(99.87%) IT(0.13%)		**0.8227**	**0.0121**	8.35E-01	4.95E-03	6.868E+08	^{234}U ^{234}Pa
^{232}U	92	6.89E+01 y	α	5.3065		**0.0002**	5.307	3.146E-02	2.140E+01	^{226}Th
^{233}U	92	1.592E+05 y	α	4.8141	**0.0055**	**0.0013**	4.821	2.857E-02	9.680E-03	^{229}Th
^{234}U	92	2.454E+05 y	α	4.7732		**0.0001**	4.773	2.829E-02	6.248E-03	^{230}Th
^{235}U	92	7.037E+08 y	α	4.3785	**0.0426**	**0.1561**	4.577	2.713E-02	2.161E-06	^{231}Th
^{236}U	92	2.342E+07 y	α	4.4793	**0.0108**	**0.0015**	4.492	2.662E-02	6.469E-05	^{232}Th
^{238}U	92	4.468E+09 y	α	4.1945	**0.0095**	**0.0013**	4.205	2.492E-02	3.362E-07	^{234}Th

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Table 4-4. (Concluded)

Nuclide	Atomic Number	Half-life[1]	Principal mode(s) of decay[2]	Major Radiation Energies[3] MeV/dis σ	Θ	$Y^{(x)}$	"Q" Value[4] (MeV/dis)	(W/Ci)	Specific Activity Ci/g	Daughter(s)
^{236}Np	93	1.550E+05 y	β(8.9%) α(0.20%)		0.1967	0.1411	3.38E-01	2.00E-03	1.317E-02	^{236}U; ^{236}Pu; ^{232}Pa
^{237}Np	93	2.140E+06 y	α	4.7604	0.0640	0.0327	4.857	2.879E-02	7.049E-04	^{233}Pa
^{239}Np	93	2.355 d	β		0.2521	0.1740	4.26E-01	2.53E-03	2.320E+05	^{239}Pu
^{236}Pu	94	2.851 y	α	5.7521	0.0126	0.0020	5.767	3.418E-02	5.313E+02	^{232}U
^{238}Pu	94	8.774E+01 y	α	5.4871	0.0099	0.0018	5.499	3.2593E-02	1.712E+01	^{234}U
^{239}Pu	94	2.411E+04 y	α	5.1011		0.0001	5.101	3.024E-02	6.216E-02	^{235}U
^{240}Pu	94	6.563E+03 y	α	5,1549			5.155	3.056E-02	2.279E-01	^{236}U
^{241}Pu	94	1.44E+01 y	β	0.0001		0.0052	5.3E-03	3.2E-05	1.030E+02	^{241}Am
^{242}Pu	94	3.763E+05 y	α	4.8901	0.0081	0.0014	4.900	2.904E-02	3.818E-03	^{238}U
^{244}Pu	94	8.26E+07 y	α(99.875%) SPF(0.125%)	4.5751	0.0007	0.0001	4.576	2.712E-02	1.774E-05	^{240}U; (fission product)
^{241}Am	95	4.327E+02 y	α	5.4801	0.0304	0.0287	5.539	3.283E-02	3.432	^{237}Np
^{242}Am	95	16.01 h	β(82.7%) EC(17.3%)		0.1781	0.0180	1.96E-01	1.16E-03	8.084E+05	^{242}Cm; ^{242}Pu
^{242m}Am	95	1.41E+02 y	IT(99.55%) α(0.45%)	0.0232	0.0403	0.0049	6.84E-02	4.05E-04	9.718	^{242}Am ^{238}Np
^{243}Am	95	7.380E+03 y	α	5.2658		0.0481	5.3137	3.1496E-02	1.993E-01	^{239}Np
^{242}Cm	96	162.94 d	α	6.0434	0.0090	0.0018	6.0542	3.5886E-02	3.306E+03	^{238}Pu
^{243}Cm	96	2.85E+01 y	α(99.76%) EC(0.24%)	5.8380	0.1129	0.1316	6.083	3.605E-02	6.162E+01	^{239}Pu ^{243}Am
^{244}Cm	96	1.811E+01 y	α	5.7965		0.0016	5.798	3.437E-02	8.090E+01	^{240}Pu
^{245}Cm	96	8.5E+03 y	α	5.3631	0.1342	0.1178	5.615	3.329E-02	1.717E-01	^{241}Pu
^{246}Cm	96	4.73E+03 y	α	5.3764	0.0072	0.0014	5.385	3.192E-02	3.072E-01	^{242}Pu
^{247}Cm	96	1.56E+07 y	α	4.9475		0.3152	5.263	3.119E-02	9.278E-05	^{243}Pu
^{248}Cm	96	3.40E+05 y	α(91.74%) SPF(8.26%)	4.6524			4.6524	2.7577E-02	4.251E-03	^{244}Pu (fission product)
^{252}Cf	98	2.645 y	α(96.908%) SPF(3.092%)	5.9308	0.0051	0.0011	5.9370	3.5191E-02	5.378E+02	^{248}Cm (fission product)

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Table 4-5
Representative DOE LLW Radionuclide Composition by Percent Activity

Uranium/thorium		Fission Product		Induced Activity		Alpha <100 nCi/g		"Other"	
Nuclide	Composition	Nuclide	Composition	Nuclide	Composition	Nuclide	Composition	Nuclide	Composition
^{208}T	0.0017	^{80}Co	0.08	^{51}Cr	4.95	^{238}Pu	2.62	^{3}H	1.22
^{212}Pb	0.0045	^{90}Sr	7.77	^{54}Mn	38.10	^{239}Pu	0.20	^{14}C	0.06
^{212}B1	0.0045	^{90}Y	7.77	^{58}Co	55.40	^{240}Pu	0.70	^{54}Mn	6.76
^{212}Po	0.0029	^{95}Zr	1.27	^{59}Fe	0.49	^{241}Pu	96.4	^{58}Co	6.24
^{216}Po	0.0045	^{95}Nb	2.83	^{60}Co	0.87	^{241}Am	0.004	^{60}Co	18.03
^{224}Ra	0.0045	^{99}Tc	0.02	^{65}Zn	0.19	^{242}Cm	0.056	^{90}Sr	8.48
^{228}Ra	0.0269	^{125}Sb	2.93		100.00	^{244}Cm	0.20	^{90}Y	8.48
^{228}Ac	0.0269	^{125m}T	0.73				100.000	^{99}Tc	0.12
^{228}Tc	0.0045	^{106}Ru	6.39					^{134}Cs	13.98
^{231}Th	0.0259	^{106}Rh	6.39					^{137}Cs	18.45
^{232}Th	0.273	^{134}Cs	0.38					^{137m}Ba	17.45
^{234}Th	33.197	^{137}Cs	17.31					^{236}U	0.73
^{234m}Pa	33.197	^{137m}Ba	16.38						
^{234}Pa	0.0034	^{144}Ca	14.67						100.00
^{235}U	0.0258	^{144}Pr	14.67						
^{236}U	33.197	^{147}Pm	0.06						
	100.0000	^{161}Sm	0.11						
		^{162}Eu	0.09						
		^{164}Eu	0.09						
		^{166}Eu	0.06						
			100.00						

Source: DOE 1991

Summary of Radiouclide Characteristics for LLW at DOE Sites[1]

Waste type	Radionuclide Characteristic [2]	Volume, m' 1990	Cumulative	1991 (projected)	Activity, Ci 1990	Total gross[4]	1991 (projected)
Generated onsite	Uranium/thorium	30,841	NA[3]	31,476	824,018	NA	1,066,623
	Fission product	21,411	NA	20,314	135,483	NA	103,764
	Induced activity	4,314	NA	4,710	225,915	NA	1,645,882
	Tritium	1,307	NA	1,191	38,475	NA	26,670
	Alpha	9,347	NA	11,428	33	NA	34
	Other	979	NA	1,465	5,069	NA	25,859
	Total	68,199	NA	70,584	1,228,993	NA	2,868,832
Stored	Uranium/thorium	5,996	42,395	4,943	11	28	18
	Fission product	366	1,284	404	133,611	2,416,148	101,760
	Induced activity	219	1,175	268	6,843	3,647,808	4,650
	Tritium	710	2,043	605	54,986	629,465	50,010
	Alpha	3,820	2,466	5,250	20	113	21
	Other	1,554	6,175	339	2,417	2,421	2,429
	Total	12,685	55,538	11,809	195,888	6,695,983	158,886
Buried	Uranium/thorium	21,347	841,559	25,268	35	861,304	70
	Fission product	18,459	1,157,195	17,447	1,634	7,572,193	1,790
	Induced activity	2,244	182,786	2,033	3,762	6,788,485	3,990
	Tritium	1,749	77,791	1,309	83,432	15,059,719	72,250
	Alpha	8,275	309,900	5,976	482	65,559	13
	Other	2,462	150,438	2,473	207,634	11,877,579	519,030
	Total	54,536	2,719,669	54,506	296,979	42,224,839	602,684

[1] Based on DOE site information provided by the Waste Management Information System,

[2] Radionuclide characteristics: (1) uranium/thorium- those waste materials in which the principal hazard results from naturally occurring uranium and thorium isotopes. The hazard from all other radioactive contaminants should be insignificant. Examples of these wastes include depleted uranium, natural uranium ore, and slightly enriched uranium; (2) fission product-waste materials that are contaminated with beta gamma emitting radionuclides which originate as a result of fission processes. Primary examples are 137_{Cs} and 90_{Sr}; (3) induced activity - waste materials that are contaminated with beta-gamma-emitting radioisotopes which are generated through neutron activation. Of major concern is 60_{Co}; (4) tritium - waste materials in which the principal hazard results from tritium (3_H); (5) alpha - waste materials contaminated with alpha-emitting radionuclides not listed under U/Th or low levels (<100 nCi/g) of TRU isotopes; and (6) other - unknown or not defined.

[3] From the beginning of operations through 1990.

[4] Sum of annual additions without decay,

[5] Not applicable.

[6] Information not available.

Source: DOE 1991

Table 4-7
Summary of Physical Characteristics for LLW at DOE Sites[1]

		Volume, m^3			Activity, Ci		
Waste Type	Physical Characteristic [2]	1990	Cumulative	1991 (projected)	1990	Total gross[4]	1991 (projected)
Generated onsite	Biological	56	NA[3]	45	< < 1	NA	1
	Contaminated equipment	18,350	NA	19,427	7,214	NA	1,188,547
	Decontamination debris	3,325	NA	5,376	890,206	NA	1,247,718
	Dry solids	30,737	NA	31,663	327,965	NA	407,939
	Solidified sludge	14,377	NA	1,871	45	NA	39
	Other	1,354	NA	12,202	3,563	NA	24,588
	Total	68,199	NA	70,584	1,228,993	NA	2,868,832
Stored	Biological	3	INA’	1	< < 1	INA	< < 1
	Contaminated equipment	1,223	INA	1,218	7,082	INA	8,574
	Decontamination debris	2,433	INA	4,381	8	INA	10
	Dry solids	3,308	INA	2,724	188,683	INA	150,175
	Solidified sludge	3,338	INA	1,818	7	INA	7
	Other	2,380	INA	1,667	108	INA	120
	Total	12,685	INA	11,809	195,888	INA	158,886
Buried	Biological	104	INA	92	< < 1	INA	1
	Contaminated equipment	15,730	INA	13,029	9,879	INA	9,299
	Decontamination debris	3,827	INA	11,110	1,467	INA	1,137
	Dry solids	29,355	INA	26,488	77,060	INA	72,250
	Solidified sludge	41	INA	46	131	INA	10
	Other	5,479	I NA	3,741	208,442	INA	591,987
	Total	54,536	INA	54,506	296,979	INA	602,684

[1] Based on DOE site information provided by the Waste Management Information System.

[2] Physical characteristics: (a) biological (sewage sludge, animal carcasses, excrete, etc.); (b) contaminated equipment (components, maintenance wastes, etc.); (c) decontamination debris (wastes resulting from decontaminatiom and decommissioning efforts, construction debris, etc.); (d) dry solids (normal plant wastes, blotting paper, combustible materials, etc.); (e) solidified sludge (any wastes solidified from a process sludge such as evaporator bottoms solidification, solidification of precipitated salts, etc.); and (f) other (materials which are outside of the above categories).

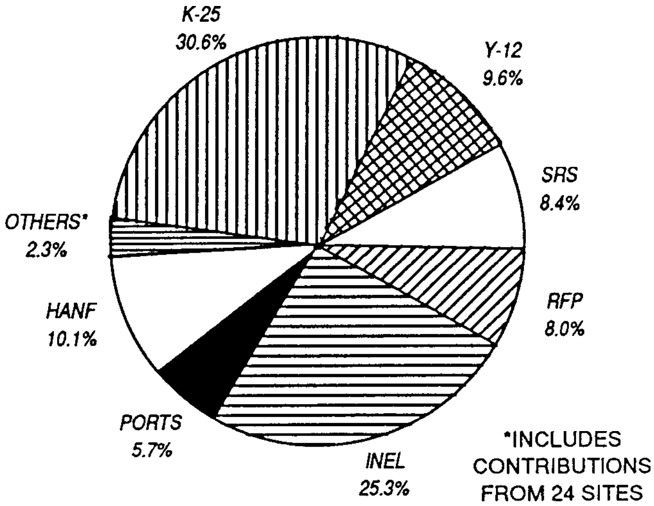
[3] From the beginning of operations through 1990.

[4] Sum of annual additions without decay.

[5] Not applicable.

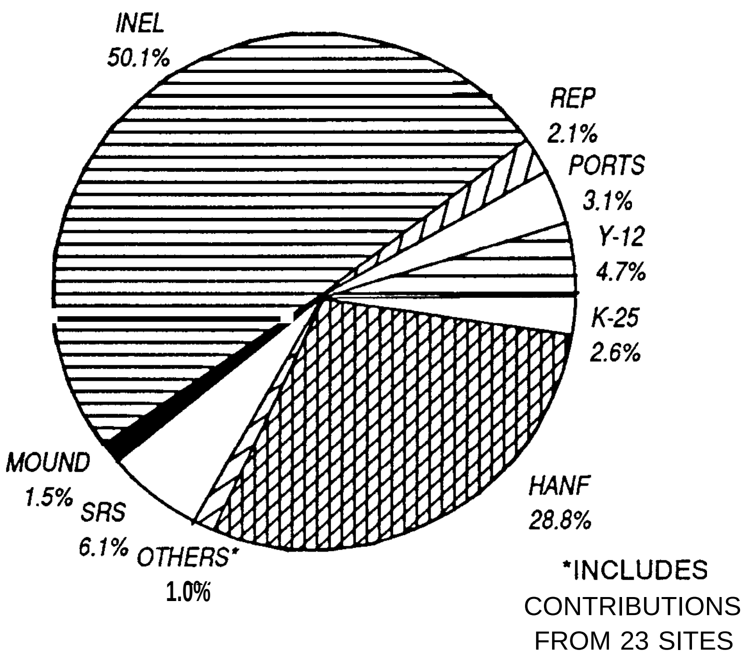
[6] Information not available.

Source: DOE 1991



SITE	CUBIC METERS
HANF	1.08E+04
INEL	2.70E+04
K-25	3.27E+04
PORTS	6.09E+03
RFP	8.49E+03
SRS	8.96E+03
Y-12	1.03E+04
OTHERS*	2.48E+03
TOTAL	**1.07E+05**

Figure 4-2. Total volume (m^3) inventory of DOE mixed LLRW through 1990



SITE	CUBIC METERS
HANF	6.38E+03
INEL	1.11E+04
K-25	5.87E+02
MOUND	3.24E+02
PORTS	6.89E+02
RFP	4.82E+02
SRS	1.35E+03
Y-12	1.05E+03
OTHERS*	2.15E+02
TOTAL	2.22E+04

Figure 4-3. Volume generation (m^3) of DOE mixed LLRW during 1990 (DOE 1991)

Table 4-8
Radionuclides Included in the ITTS Study Database

Alpha	Fission Products	Induced Activity	Tritium
Am-241	BA-1 37	Co-56	H-3
Pu-239	Ce-144	Co-60	
Pu-241	Cs-134	Cr-51	Uranium/ Thorium
	Cs-137	Fe-59	Pa-234
	Nb-95	Mn-54	Th-234
	Pr-144	Te-99	U-235
	Rh-106	Zn-65	U-238
	Ru-106		
	Sb-125		
	Sr-90		
	Te-125m		
	Y-90		
	Zr-95		
Other	This category is made up of a combination of any of the above radionuclides.		

(6) Waste oil from contaminated equipment, systems, and work areas.

(7) Trash with oil from radioactive systems and work areas.

(8) Chlorinated fluorocarbon (CFC) solvents.

(9) CFC concentrates from laundry and tool decontamination.

(10) Aqueous corrosive liquids from cleaning spent fuel casks and resin filters.

(11) Chromate wastes from resin changeouts in Light Water Reactors (LWRS).

(12) Cadmium wastes from spent LWR equipment and cleanup activities, including spent welding rods, weld cleaning, and equipment decontamination.

4-4. Observed Radionuclide Components in MW

The U.S. Army Corps of Engineers has observed typical radionuclide contents in disposal items, as shown in Table 4-12.

Table 4-9
Quantities of Contacted-Handled Low-Level Mixed Wastes Derived for the ITTS Study[1]

Facility	State	Net Weight (Kg)	Drums (Kg)	Bins (Kg)	Total Weight (Kg)
Total LLMW:		141,560,474	10,055,196	4,677,120	156,292,790
Argonne National Laboratory-East	Illinois	142,892	12,848	580	156,320
Brookhaven National Laboratory	New York	64,637	11,642	290	76,769
Energy Technology Engineering Center	California	1,173,844	85,466	1,160	1,260,470
Fernald Environmental Management Project	Ohio	2,987,064	415,010	2,030	3,404,104
Hartford Site	Washington	4,494,859	697,515	24,070	5,216,444
Idaho National Engineering Laboratory	Idaho	13,567,705	835,385	1,305,290	15,708,380
Lawrence Livermore National Laboratory	California	166,778	24,461	3,190	194,429
Los Alamos National Laboratory	New Mexico	1,063,295	67,532	18,850	1,149,677
Middlesex Sampling Plant	New Jersey	41,805,426	0	2,238,510	44,043,936
Oak Ridge National Laboratory	Tennessee	267,789	37,015	6,670	311,474
Oak Ridge National Laboratory, K-25 Site	Tennessee	35,645,796	4,263,323	15,660	39,924,779
Oak Ridge National Laboratory, Y-1 2 Plant	Tennessee	17,496,920	1,192,562	432,100	19,121,602
Paducah Gaseous Diffusion Plant	Kentucky	203,037	28,518	3,480	235,035
Pantex Plant	Texas	67,393	6,321	4,060	77,774
Portsmouth Gaseous Diffusion Plant	Ohio	5,477,490	577,975	271,730	6,327,195
Puget Sound Naval Shipyard	Washington	58,360	5,939	2,030	66,329
Rocky Flats Plant	Colorado	13,970,130	1,412,464	56,260	15,438,854
Savannah River Site	South Carolina	2,651,122	364,472	290,000	3,505,594
Weldon Spring Site	Missouri	53,936	10,613	0	64,549

[1]Quantities obtained from the DOE/NBM-l 100 (MWIR Report) (DOE 1993). The Hanford tank waste (40,086 Kg) and the RFP

Table 4-10
DOE Complex Contacted-Handled Low-Level Mixed Wastes per Waste Category - Derived for the ITTS Study[1]

Waste Categories[2]	Net Weight (Kg)	Drums (Kg)	Boxes (Kg)	Total Weight (Kg)	Density (Kg/m^3)
Total CH LLMW:	**141,560,474**	**10,055,195**	**4,677,120**	**156,292,790**	
Aqueous Liquids	2,202,248	306,701	0	2,508,949	1,013
Batteries	13,682	1,646	0	15,329	1,397
Beryllium Dust	300	235	0	535	200
Cemented Solids	274,651	10,349	8,410	293,409	1,570
Compressed Gases	2,642	323	870	3,835	548
Contaminated Metals	39,581	0	4,060	43,642	960
Elemental Lead	731,148	20,462	31,030	782,640	3,252
Heterogeneous Debris	2,226,795	77,587	355,540	2,659,923	635
Inorganic Debris	43,928,872	146,412	2,394,240	46,469,524	1,240
Inorganic Sludge/Particulates	52,580,798	6,203,626	16,530	58,800,954	1,109
Lab Packs with Metals	547,877	89,758	0	637,636	1,001
Lab Packs without Metals	656,299	108,045	0	764,343	849
Liquid Mercury	363,947	6,262	0	370,209	7,722
Multiple	17,663,553	1,366,976	980,490	20,011,019	946
Organic Debris	1,086,298	116,983	398,460	1,601,741	567
Organic Liquids	2,939,802	504,827	0	3,444,629	902
Organic Sludge/Particulate	2,763,797	366,912	20,590	3,151,299	917
Other	612,037	87,965	9,860	709,861	802
Reactive Metals	25,154	1,617	4,350	31,121	656
Soils	12,791,755	626,720	452,690	13,871,165	1,359
Soils with < 50% Debris	109,239	11,789	0	121,028	1,332

[1] Quantities obtained from the DOE/NBM-1100 (MWIR Report) (DOE 1993). The Hanford tank waste (40,086 Kg) and the RFP aqueous solar pond waste (45,425 Kg) were excluded.
[2] Waste categories were obtained from the DOE/NBM-1100 (MWIR Report) (DOE 1993).

Table 4-11
Volume Generation Rates (m^3) of DOE Site Mixed LLW, by Physical Category, for 1990[1,2]

Site	Solid	Liquid	Gas[3]	Sludge	Total
Ames	0	0	0	0	0
ANL-E[4]					
ANL-W	0.31	0	0	0.31	0.31
BNL[4]					
FMPC[4]					
FNAL	0	0.01	0	0.01	0.01
HANF	6,372.00	4.50	0	0	6,376.50
INEL	25.93	11,076.50[sic]	0	115.30	587.50
ITRI[4]					
KCP	0.31	0	0	0	0.31
K-2	259.80	211.40	0	116.30	587.50
LANL	46.05	13.73	0	70.56	130.34
LBL[4]					
LLNL[4]					
MOUND	322.10	1.48	0	0	323.58
NR sites[5]	1.01	0	0	0	1.01
NTS[4]					
ORNL[5]	0.79	6.78	0	0	7.57
PAD[4]					
PANT	8.32	2.49	0	0	10.81
Pinellas	0	0	0	0	0
PORTS	532.40	104.00	0	52.50	688.90
PPPL	0	0.02	0	0	0.02
RAP sites[5]	62.92	1.79	0	0	64.71
RFP	418.25	0	0	44.00	462.26
RMI[4]					
SLAC	0	0	0	0	0
SNLA[4]					
SNLL	0.05	0.32	0	0	0.37
SRS	144.90	1,204.90	0	0	1,349.80
WVDP	0	0.01	0	0	0.01
Y-1	164.90	30.00	0	858.00	1,052.90
Total	8,360.05	12,657.93	0	1,144.82	22,152.80

[1] Materials may be in interim storage awaiting treatment.
[2] Densities of 1,000 kg/m^3 for liquids, 500 kg/m^3 for gases, and 1,500 kg/m^3 for solids and sludges were assumed to calculate volumes when the site did not report volume data.
[3] Stored in cylinders.
[4] Updated information for 1990 was not available from this site.
[5] Includes contributions from Bettis (BAPL) and NRF (INEL).
[6] Includes a small contribution from Oak Ridge Associated Universities (ORAU).
[7] Includes contributions from Battelle (BCLDP), Colonie (CISS), Grand Junction (GJPJO), Santa Susana (SSFL), and Weldon Spring (WSSRAP).

Source: DOE 1991

Table 4-12
Radionuclides Observed in Typical Disposal Items[1]

Description	Nuclide	Activity in μCi
Instruments and Articles (Activities listed are per item. Items may be packaged in large quantities.)	U-238	2.27e+01
	TL-204	1.60e+03
	TH-232	8.70e+01
	TH-232	2.30e-08
	TH-230	1.20e+00
	TH-230	1.00e-02
	SR-90[2]	1.80e+05
	SR-90	5.00e-01
	RA-226	1.00e+03
	RA-226	1.00e-03
	PU-239	5.02e+01
	PU-239	1.00e-02
	PM-147[2]	3.00e+03
	PM-147	1.00e+01
	PB-210	2.00e-02
	PA-234	1.00e+00
	NI-63[2]	1.20e+04
	NI-63	5.00e+00
	KR-85	5.00e+04
	KR-B5	9.00e-04
	1-131	1.00e+00
	H-3	3.70e+07
	H-3	9.00e-02
	DEPLETED URANIUM	1.80e+07
	DEPLETED URANIUM	3.60e+01
	CS-137	1.00e+00
	CS-137	1.00e+00
	CO-60[2]	1.08e+09
	CO-60	9.00e-02
	C-14	1.00e+00
	BI-210	1.00e+00
	9A-133	1.00e+00
	AM-241/BE2 (neutron source)	4.00e+06
	AM-241[2]	5.00e+04
Contaminants		
Soils, building materials, debris	RA-226	2 nCi/gm max
Radium needles	RA-226	1.00e+10
Liquid scintillation vials (toluene and xylene)	H-3/C-14/S-35/CL-36/P-32/1-125	<5.00e-02
Medical and research wastes, animal carcasses	MIXED FISSION PRODUCTS H-3/C-14/S-35/CL-36/P-32/1-1 25/C0-60/ CS-1371SR-90	UNKNOWN
Soil	CS-1371SR-85 SUDAN MIX	2.00e+04
Rocket skin, frame, motor parts	TH-232	4% by wt 500 lb
Soils and drums	CO-60	up to 100 mR/hr in 8-oz. soil sample, unknown total

(Continued)

[1] Instruments and articles may contain hazardous materials
[2] Indicated calibrator source (scaled sources).

Table 4-12 (Concluded)

Description	Nuclide	Activity in μCi
Soils	TRANSURANICS	UNKNOWN
	CD-???	1.61e+02
	AM-241	2.27e+05
	I-129	2.99e+01
	I-131	DECAYED
	U-238	7.13e+01
	PU-239	1.18e+05
	PU-238	7.56e+04
	CM-244	1.93e+04
Nuclear reactor decommissioning	SOURCE, BYPRODUCT, SPECIAL NUCLEAR MATERIALS	UNKNOWN
Ordnance and armor in soils and building materials	DEPLETED URANIUM	UNKNOWN
Soils	CS-137	<1 nCi/gm
	SR-90	<2 nCi/am